Name	Affiliation	Comment	Citation
John Satterfield	Chesapeake Energy	The report presents a thorough evaluation of published literature, the National Academy of Sciences (NAS) report and case histories. It should be noted however there is new information that is being developed, though unfortunately unpublished at this time, concerning the issue of induced seismicity related to UIC wells, geothermal projects, mining, and other anthropogenic activities that could inform this work. This information should be considered by EPA if there is future consideration of review/revising of the approaches in your draft report.	General
John Satterfield	Chesapeake Energy	The sole purpose of the UIC regulations is the protection of Underground Sources of Drinking Water (USDW). It should be noted the only way induced seismicity can pose a threat to a USDW is if there is a fault (flow path allowing injected water to enter the USDW) that transects the confining layers (typically 1000's of feet) between the injection zone and the USDW thus connecting the injection zone and the USDW. And the only way the seismic event becomes a reality is if the fault is triggered because the fault is critically stressed and the pore pressure impacts the in situ stress field, thus allowing the flow path to open up (breakthrough).	General
Bill Bates, Ross Micham, Tim Elkins	EPA Reg 5	If the discussion about hydraulic fracturing is retained, Region 5 suggests adding a definition of HF including when it is considered UIC regulated injection. The report title refers to induced-seismicity from Class II disposal wells.	General
Dave Basinger	EPA Rg 9	Is this report intended to result in specific new procedures during UIC permit application evaluations? If not, why not? If so, could that be clarified?	General
Vince Matthews	Former: CO State Geologist	I am impressed by the depth and breadth of this report. In my judgement it is balanced and thorough. I would recommend this report to professional geoscientists, regulators, and policy makers alike as an excellent primer and reference on the issue of induced seismicity and its potential mitigation in UIC Class II injection wells. It is quite readable at the overview level. The appendices provide excellent documentation of key case histories and provide in-depth first principles for technical workers. I suspect that it will quickly become an important reference for the oil and gas industry, as well as many in academia.	General
C.S. Kabir	Hess Corp	Use of modified Hall Plot: His experience suggests this tool is ideally suited for real-time monitoring of injection performance and was quite pleased to see its extensive use in the report.	General
Ernie Majer	LBNL	The discussion was too general, with no talk about uncertainties. You have all the information but it could be organized better.	General
Bill Smith	NAS	Noted work product's compilation of data to 4 case histories and introduction and illustration of PE techniques and methodologies to analyze the data.	General
Bill Smith	NAS	Bill has found it useful to plot the seismic events at their depth on cross-sections as well as in a map view even recognizing the depth estimates are typically less accurate than the epicenter locations, but still serve a useful purpose to understand where fluids have moved to and possible path taken.	General
David Dillon	NAS	Noted work product's wealth of info and great amount of original technical analysis that sheds new light on physical causes of induced seismicity.	General

Tom Tomastik	ODNR	The mention of hydraulic fracturing and induced seismicity should be eliminated from this report as this report is focused exclusively to Class II injection.	General
Tom Tomastik	ODNR	I have seen Ohio EPA's comments and agree with their recommended changes.	General
Chuck Lowe	OH EPA	Is it a guidance or procedure? The Ohio EPA recommends that the document be split into two. One, a guidance aimed at the general public and the second a technical procedural document for permit reviewers and inspectors. This current draft document is very dissatisfying as either a guidance or a procedural document. It is very generic with regards to both and leaves the permit writer or inspector confused as to what steps need to be taken if there appears to be a concern about induced seismicity. The guidance document can be written for the general public. It can include the case studies and general information on what factors can cause induced seismicity. The procedural document can be more technically written with information on: the factors that can cause induced seismicity; the sitting and geologic issues to account for when reviewing a permit or report; the tests and additional information to require if induced seismicity appears to be a concern; and the legal authority to require the additional tests and information. The procedural document should be organized to stress the Decision Model.	General
Norman Warpinski	Pinnacle-Halliburton	This is report is a very nice compendium of information about induced seismicity in UIC Class II disposal wells. I would suggest, however, that you have put the cart before the horse in doing this study. The report implies, if not outright states, that the purpose of the mitigation of induced seismicity is to protect USDW's. It would seem logical, then, that the first study should have been one to determine if there is any possibility that induced seismicity from UIC Class II disposal wells (and related injection activity) could actually impact USDW's in any way, negative or positive. Such an impact study would have required a study of all injection wells in which there was some potential for induced seismicity (proved or otherwise), a study of groundwater quality or issues in the areas around the injection sites, geologic studies to evaluate structural and stratigraphic conditions around the sites, some appropriate modeling to estimate reservoir conditions and possible migration, and realistic risk analysis studies of the results. If the conclusion were affirmative, then the present study would be the appropriate follow up. However, if the study were to return a negative result, then it is not clear to me what role the EPA should play relative to induced seismicity. It is certainly true that induced seismicity from these wells could have other impacts (e.g., surface damage) that would need to be handled by some appropriate regulatory body. As the permitter of the well, is the EPA also charged with regulating seismicity if it is not a threat to a USDW? It is not written into the law anywhere that I can find, since the discretionary authority appears to be relative to the USDW's, but if so, this should be stated in the text. For example, item 9 of 40 CF$ 144.52 states "The Director shall impose on a case-by-case basis such additional conditions as are necessary to prevent the migration of fluids into underground sources of drinking water." I could not find any broader authority, so you really should cite the appropriate law if it exists.	General

Norman Warpinski	Pinnacle-Halliburton	I was surprised that this report did not try to put the problem into context. It would seem that first thing to be done was to provide information on the number of Class II UIC wells, the number of disposal wells, how they are distributed in the US, how long they have been operating, how many have had potential problems (proved or otherwise), and some overall idea of how significant or severe this issue might be. Without this context, the average reader (public, press, legislators) might conclude that there are only a few disposal wells and most of them are problems, which is far from reality. Did you intentionally intend to leave this impression?	General
Brian Stump and Chris Hayward	SMU	We both found that the report provided practical insights into problems related to induced seismology. In particular, it does a good job of articulating the need for an inter disciplinary approach to solving this important issue involving expertise from seismology to petroleum engineering. Moving forward will require open and frank exchanges of data and expertise.	General
Brian Stump and Chris Hayward	SMU	We both felt that with the publication of the recent National of academy of Sciences Report consideration might be given to explicitly discussing the similarities and differences in the conclusions of the two reports.	General
	USGS	We also recommend as part of the permitting process, hourly measurements of injection volumes and pressures be recorded in a publicly accessible national database of Class II wells. This database should be complete (containing every well in every state) and contain all basic permitting information in addition to operational parameters.	General
	USGS	Also of note is that, ideally, these regions would be instrumented seismically prior to permitting the wells. With seismic instrumentation in place and operating before fluid injection, the regulator would have a direct measurement of the background rate of seismicity and would be able to monitor the evolution of the seismicity in the field should any occur. This would assist with the management of the risk.	General
	USGS	**SUGGESTED PERMITTING GUIDELINES FOR MINIMIZING INDUCED EARTHQUAKES**	General
	USGS	**Permitting Guidelines**	General
	USGS	*Well Monitoring*	General
	USGS	● Fluid pressures and volumes should be recorded at intervals of one hour, or less, and reported in a publicly accessible database.	General
	USGS	o For wells under gravity feed, pressure monitoring must be below the fluid surface.	General
	USGS	o For wells under pressurized injection, monitoring may be at the well-head.	General
	USGS	· Monitoring data for all wells should be available from a single, searchable, national database of fluid-injection wells that is current within no more than 6 months. This database should contain basic UIC permit information and the injection pressures and volumes described above.	General
	USGS	*Seismicity*	General
	USGS	● The rate of earthquake occurrence within 20 km of the site should be documented with the purpose of knowing the background seismicity rate of the region. The Advanced National Seismic System Catalog (ANSS) should be used: http://www.ncedc.org/anss/catalog-search.html	General

	USGS	● The expected rate of earthquake occurrence for the region from the US National Seismic Hazard Map should be calculated. The value reported only goes down to magnitude 5 earthquakes, but can be extrapolated for smaller events.	General
	USGS	https://geohazards.usgs.gov/eqprob/2009/index.php	General
	USGS	● Earthquake rates for Magnitude 2.0 – 2.9 and 3.0 – 3.9 can be used as a measure of the background seismicity.	General
	USGS	*Geologic Structures*	General
	USGS	● All mapped faults in the vicinity of the wells should be considered.	General
	USGS	o The presence of active injector wells in the region may indicate that there is a low likelihood of a new well inducing earthquakes.	General
	USGS	o Seismic monitoring with a detection completeness threshold of M=2 will be needed to determine if there are significant changes in the seismicity rate or activation of structures not seen prior to the start of injection.	General
	USGS	*Vulnerabilities to Earthquake Strong Ground Motion*	General
	USGS	● The risk posed to critical structures located within 20 km of the site should be considered (e.g., nuclear power plants, dams, bridges).	General
	USGS	*Fluid Flow*	General
	USGS	● Permeability & Fluid Pressure of the target formation should be characterized.	General
	USGS	*Contingency*	General
	USGS	● Permit is contingent on the maximum strength of earthquake ground motions (shaking) observed for potentially induced earthquakes not being exceeded.	General
	USGS	o Preferably this would be determined from direct measurement by seismometers and accelerometers.	General
	USGS	o Modified Mercalli Intensity (MMI) can be used as a proxy for strength of shaking:	General
	USGS	▪ The “Did You Feel It” portion of the USGS website estimates MMI.	General
	USGS	▪ The USGS product “Shakemap” determines instrumental intensities.	General
	USGS	o Earthquake magnitude can be used as a proxy for strength of shaking.	General
	USGS	● Permit is contingent on the length of fault structures illuminated by induced seismicity remaining below a threshold value.	General
	USGS	● Permit is contingent upon the earthquake rate remaining below a threshold value.	General
	USGS	● Permit is contingent upon the level of public response to the earthquakes	General
Cliff Frohlich	UT BEG	Report brought together a great deal of information in a single document including some information which he had not seen or do not have access to elsewhere. Thus if published without further revision he suspects many other researchers would find it useful. He also appreciated the sections written from the perspective of reservoir engineers.	General

Cliff Frohlich	UT BEG	Report's intended audience was unclear. 1) Opening suggests the effort came about because of concerns about drinking water; however, the body of the report and appendices don't discuss whether induced earthquakes have or might affected drinking water. He is unaware of any situation where induced seismicity adversely affected drinking water. Drinking water is hardly mentioned after the initial section. 2) Parts of the report read like it is intended as a maual for policy-makers and even well operators, but if this is the audience the report includes a lot of detail that is confusing.	General
Cliff Frohlich	UT BEG	Over the past year the NRC, ODNR, British Columbia O&G Commission and Royal Society and Royal Academy of Engineering (UK) all published reports on potential hazards related to induced seismicity. I would think the EPA report would want to describe how their report and objectives differed from the other efforts.	General
Cliff Frohlich	UT BEG	Parts of the report seem out-of-date, which is troubling considering that it hasn't yet been released publically. This is partly because much of this material appears to have been prepared in 2011. It also may be inevitable simply because induced seismicity is a fast-changing field. Several papers on the Arkansas and Texas quakes that appeared in 2012 aren't discussed, referenced in the report body, or in Appendix K.	General
Cliff Frohlich	UT BEG	The report completely avoids the fact that there are enormous cultural variation in the population's willingness to live with small earthquakes, and enormous variations in population density that should undoubtedly affect how possible policy or regulations affecting injection wells should implemented. For example, in Texas alone, there are tens of thousands of injection wells, some in operation for more than 50 years; most haven't caused any earthquakes. Indeed, in parts of west Texas wells have been causing earthquakes for decades – near Snyder these include an M4.6 in 1978 and an M4.3 in 2011 – but if it's not oil or football, (say the locals) who cares? Then, an M3.0 in 2008 in Dallas-Fort Worth caused considerable concern locally; if it happened in California local residents might not consider it a problem. And of course, it makes sense that regulations should be different for sparsely-populated small town west Texas than for a huge populations center like DFW. Although the report makes numerous suggestions concerning policy recommendations or possible requirements for assessing 'new' injection wells, these suggestions don't take account of huge differences in potential hazard related to population density, or to how risk-averse various populations may be.	General
Cliff Frohlich	UT BEG	I appreciated the sections written from the perspective of reservoir engineers. These were enlightening to me as plain-vanilla earthquake seismologist like myself don't know much about that world and it is clear that it has much to offer.	General
Cliff Frohlich	UT BEG	Differentiate and describe how EPA report and objectives differed from other efforts. Over the past year the National Research Council, the Ohio Department of Natural Resources, the British Columbia Oil and Gas Commission, and the Royal Society and Royal Academy of Engineering (UK) all have published reports on potential hazards related to induced seismicity.	General

Cliff Frohlich	UT BEG	Although the report makes numerous suggestions concerning policy recommendations or possible requirements for assessing 'new' injection wells, these suggestions don't take account of huge differences in potential hazard related to population density, or to how risk-averse various populations may be.	General
Cliff Frohlich	UT BEG	I'm not knowledgeable about EP standards for reports; however, this report might benefit from some serious cutting. As it is, parts of it read much like early drafts of some Ph.D. theses I see, where the student hasn't yet confronted the fact that the audience doesn't want to see preserved every single data point, graph, or analysis that went into the research effort. For example, Appendix D on Texas quakes alone includes 84 figures. Are these all necessary? Are even a dozen necessary?	General
Tom Tomastik	ODNR	Need a discussion of injection above formation parting pressure and how some of these historical studies induced seismicity due to injection above parting pressure.	General - Reservoir aspects
Tom Tomastik	ODNR	Need to define earthquakes versus microseismic events. It is my understanding that the USGS defines an earthquake as a seismic event of greater than 2.5 magnitude.	General or Glossary
John Satterfield	Chesapeake Energy	Decision model	Decision Model
John Satterfield	Chesapeake Energy	a) Not all questions presented in the assessment model are pertinent to existing wells.	Decision Model
John Satterfield	Chesapeake Energy	i) Necessary data for characterizing reservoir pathways and the in situ stress fields can only be obtained by obtaining data when drilling new wells.	Decision Model
John Satterfield	Chesapeake Energy	ii) The most important and only questions necessary for existing wells are about historic regional seismicity and if there is a demonstrated history of successful disposal activity.	Decision Model
John Satterfield	Chesapeake Energy	(1) NAS reports that out of approx. 30,000 Class II salt water disposal wells, only 7 have had a magnitude of >4.0.	Decision Model
John Satterfield	Chesapeake Energy	b) The questions do not address the potential for impact: demographics, environmental, structural including buildings, dams, and bridges.	Decision Model
John Satterfield	Chesapeake Energy	c) Better assessment questions that address both existing (only wells that have been suspected of induced seismicity or are in an areas where local conditions warrant) and new wells are:	Decision Model
John Satterfield	Chesapeake Energy	i) Is disposal near or in basement rock?	Decision Model
John Satterfield	Chesapeake Energy	ii) Is disposal near a known fault?	Decision Model
John Satterfield	Chesapeake Energy	iii) Is the disposal well located in a "high impact" area (proximity to dense population, public structures, environmentally sensitive sites)?	Decision Model
John Satterfield	Chesapeake Energy	iv) Is disposal well located in a seismically active area?	Decision Model
John Satterfield	Chesapeake Energy	v) Are known epicenters near the disposal site?	Decision Model
John Satterfield	Chesapeake Energy	vi) Is injection coincident with known seismicity?	Decision Model

John Satterfield	Chesapeake Energy	d) The model, as presented, appears to be meant as a “one size fits all model”. This approach will result in unnecessary work given the historical infrequency of induced seismicity versus the high level of historic UIC activity. The model should be a fit for purpose model that is scalable for the potential risk of induced seismicity (probability of occurrence) and the level of impact should induced seismicity occur.	Decision Model
Denise Onyskiw	CO DNR	The only significant comment we have is that the flow chart is too simplistic. This is a great research document but UIC engineers are not geophysicists and there is no specific process for an engineer permitting a new or existing well to follow.	Decision Model
Denise Onyskiw	CO DNR	This document talks a lot about existing wells with seismic issues and what kind of studies were performed after the fact. What do we do if we have an application for a well in an area that may or may not have seismicity? Or an area such as Raton Basin where there is seismic activity but it is not clear that it is being caused by existing injection, a hot spot, or both? Colorado is a tectonically active state even without injection activities.	Decision Model
Steve Platt	EPA Reg 3	I don't know if I'm interpreting the model incorrectly, but if I answer yes to the first question, which I think would be a good thing, it puts me into the loop to do more, which I don't think is correct. Likewise, if I answer no to question 3, it puts me into the "normal permit processing", which I don't think it should. You would want to do more characterization in this case. So, my point would be that the consideration questions need to be worded in the correct way so it sends you through the model correctly. If I'm incorrect in my interpretation just disregard.	Decision Model
Steve Platt	EPA Reg 3	If you get to the end of the model, could it reference where to go in the report to provide you with examples to consider for resolution? I know if you read the report it provides examples to consider, but it may be good to have the model cycle you back to the examples.	Decision Model
Ernie Majer	LBNL	Also very little discussion of how uncertainties and risk will be handled. The bottom line is will the risk be too high to allow the injection? How will you calculate it?	Decision Model
Ernie Majer	LBNL	Risk can be lowered by proper monitoring and injection control (or by insurance) (risk of having the public go to your local authorities/congressmen).	Decision Model
Bill Smith	NAS	Decision model: Put less emphasis on Site Assessment evaluations preceding disposal operations and much more on the monitoring, evaluation and regulation of active disposal opeartions and their perceived effects. Commenter provided revised decision model and discussion appendix.	Decision Model
David Dillon	NAS	Decision model on page 25 seems logical, but based on the summary shown in Table 1, not sure any geologic analysis during the permitting process can foretell within a reaonable possible error that inj activities will or will not trigger seismic events. Lack of correlation id demonstrated by the lack of geologic correlation with TX and AR earthquake swarms.	Decision Model

David Dillon	NAS	Agreed the report is on the mark when it notes that induced seismicity is caused by a combination of PBU and a pathway for the increased pressure to communicate with a "critically" stressed fault. However, based on his provided Table 1, not sure the report answers the project objectives concerning "what parameters are most relevant to screen for" or "what screening or monitoring approaches are considered most practical and feasible" to evaluate significant inj induced seismicity.	Decision Model
Chuck Lowe	OH EPA	The Decision model should be expanded to be clear on what steps can be taken when proceeding with a permit review or inspection to determine if induced seismicity is a concern and what tests and information to require if induced seismicity appears to be a concern. This would focus the reader's attention on the site assessment methods and the key components necessary to evaluate the potential for induced seismicity.	Decision Model
Chuck Lowe	OH EPA	Ohio EPA recommends a multi-discipline approach be stressed in the procedure to perform a site assessment (geologic, geophysical, and reservoir engineering). These site characterization parameters are necessary to properly document the geologic conditions and access the potential for induced seismicity. These discussions should clarify the Decision Model.	Decision Model
USGS Comments based on 6/12 report	USGS	Decision model does not provide adequate, specific guidelines for deciding whether or not to issue a permit. Additionally, the permit should be contingent upon the seismicity remaining at acceptable levels. It is critical that there be contingencies in the permit because there are risks inherent to fluid injection, but these risks can be managed [National Research Council, 2012]. Criteria describing acceptable levels of seismicity would include maximum strength of shaking, public response, and earthquake rates. If seismicity exceeds any these parameters, the operators should have specific procedures for reducing the seismicity.	Decision model

	USGS	We suggest a traffic-light model, like the one described in Häring et al., (2008). Our suggestions for the guidelines are detailed below. Contingency Guidelines Should any of the contingency criteria be exceeded, the traffic-light response system shall be put into effect. We suggest using a system based upon the one used in Basel, Switzerland [Häring et al., 2008], modified to be appropriate for fluid-injection induced seismicity in the United States. This system was effective in that there were no earthquakes that caused significant structural damage in Basel while this system was in place. The Deep Heat Project in Basel, however, was terminated owing to the magnitude 3.4 earthquake that was induced. In this system, the well is initially in a “green” status, during which the well operates as permitted. “Yellow” would indicate a case when earthquake ground motions or seismicity rates have reached the level defined in the contingency. Should the well be put into “yellow” status, the actions described below should be undertaken. “Red” would indicate a case when earthquake ground motions or seismicity rates have reached unacceptable levels. Should the well reach “red” status, the actions described below should be undertaken. To use the traffic-light criteria, specific thresholds for earthquake rate, activated fault length, public response, and strength of shaking need to be generated for both the “yellow” and “red” cases. An expert panel should determine these thresholds. Response to Exceeding Yellow Criteria 1. Reassess the seismic hazard posed by the well in light of changes in seismicity or observed ground motions; 2. Remedial actions should be take to lower the seismicity rate and maintain ground motion levels below the acceptable threshold. Response to Exceeding Red Criteria 1. Well should be shut-in and, if necessary, allowed to flow back.;	Decision Model
Ernie Majer	LBNL	I would not agree with this flow chart, i.e., this implies that if no issues were identified one would proceed to normal permit processing, also if it was a yes, one would not allow normal permit processing. It will depend upon the risk that I.S. would pose and that depends on volume injected, probability of a “significant” event (which is also site dependent), length of injection, response to pressure changes, etc. It s not that simple!!	Decision Model, Fig 1
David Dillon	NAS	Need to correct reference Glossary in footnote on pages 1 and 3 of Exec Summary. App J is incorrect.	Page 1 and 3
Sarah Roberts	EPA Rg 8	Change "used" to "uses"	Page 1, Line 13
Sarah Roberts	EPA Rg 8	Change "considering to "and considered"	Page 1, Line 18

Bill Bates, Ross Micham, Tim Elkins	EPA Reg 5	Suggest adding the descriptor "injection" or "UIC" before the word "permit".	Page 1, line 27
Ernie Majer	LBNL	Is a corrective action equal to mitigation? Mitigation in some operators view could also be such things as insurance/money to affected groups,increased public outreach, as well as modifying injection operations.	Page 1, line 27
Sarah Roberts	EPA Rg 8	states that the report focuses on Class II because they have been suspected of induced seismicity. Is this why the report focuses on Class II or is the reason that, as described above on the page, increased production and therefore use of 2D wells in previously unproductive areas is creating a need for investigating the potential for induced seismicity in new locations	Page 1, Lines 15-16 and Page 3, lines 6-9
Ernie Majer	LBNL	In general yes, but I would say pressure changes rather than pressure build up (remember the largest events often occur after injection stops.)	Page 2, lines 1-3
Brian Stump and Chris Hayward	SMU	Although mentioned later in the report, temperature and chemical effects associated with injected fluids as mechanisms for induced seismicity are possible but in light of this current study not probable.	Page 2, lines 2-3
David Dillon	NAS	When discussing induced seismicity, reference is normally to "critically" stressed faults, not just stressed faults and may convery the wrong impression to people unfamiliar with the mechanics of induced seismicity. All faults are stressed, so "critically" stressed fault is more appropriate in the context of this report.	Page 2, line 2 and footnote 3
John Satterfield	Chesapeake Energy	The use of reservoir engineering techniques for monitoring pressure and flow are indicators only and do not provide conclusive scientific evidence of induced seismicity, a pending threat of induced seismicity or a threat to USDW.	Page 2, line 8 and Page 19, line 35
Brian Stump and Chris Hayward	SMU	It is important to note that proof of induced seismicity is difficult to achieve. I agree that it is not a prerequisite for prudent action. I think it is worth adding at this point that a single coherent physical model of the process does not exist but a collaborative program to improve the model would be of benefit in addressing these problems.	Page 2, lines 8-9

Norman Warpinski	Pinnacle-Halliburton	you state that “this absence [historical seismicity] may be a supportive indicator of induced seismicity if events occur following activation of an injection well”. This really depends on the seismic monitoring history. If there were no local USGS or other seismic stations prior to some date, and then a university or state (or Earthscope) puts an network in place, you are sure to pick up more seismicity. This cannot be sensibly used as any proof. I would add an additional phrase to the end of that sentence to the effect of “assuming there is an accurate history of seismic monitoring in the suspected injection region”.	Page 2, line 9
Ernie Majer	LBNL	Not clear, elaborate	Page 2, line 7-9
Brian Stump and Chris Hayward	SMU	It might be worth noting that this better understanding will come about by collaborative work between a wide variety of individuals in industry, government and research. This is particularly the case for combining earthquake seismology, a field with theory developed principally in academia with observations and operations by civil authorities with combinations of reservoir engineering and exploration geology and geophysics developed principally in industry.	Page 2, lines 16-19
Sarah Roberts	EPA Rg 8	Change "geosciences" to "geologic"	Page 2, Line 17
Sarah Roberts	EPA Rg 8	should read "The NTW recommends that future research..."	Page 2, Line 20
Sarah Roberts	EPA Rg 8	semicolons should be commas	Page 2, Line 22
Brian Stump and Chris Hayward	SMU	It is worth adding that the sequestration of CO2 underground could add another source human activity---induced earthquakes.	Page 3, 3rd paragraph
Brian Stump and Chris Hayward	SMU	This report does not otherwise mention the hazards to USDW and some of us are left wondering how those hazards are defined and whether examples of such hazards might be given. For example, would widespread sanding of existing DW wells be considered a hazard or disturbance of filter beds in water processing plants or is it just contamination of existing underground potable water? If the later, is there an example – or an example from natural EQ occurrence?	Page 3, footnote 6
Norman Warpinski	Pinnacle-Halliburton	it would seem appropriate to state how induced seismicity could interfere with “containment of injected fluids and endanger drinking water sources”. What are the mechanisms by which this endangerment occurs (same as my overlying theme at the beginning).	Page 3, line 12
Norman Warpinski	Pinnacle-Halliburton	you might also add “erection of skyscrapers” to your list. It really puts into context how many varied ways (not just extraction and reservoirs) man might induce seismicity.	Page 3, line 19
Chuck Lowe	OH EPA	run on sentence, change to read “…hydraulic fracturing (HF) was addressed by review of selected literature sources. The WG agrees with the conclusion	Page 3, line 23
Bill Bates, Ross Micham, Tim Elkins	EPA Reg 5	Suggest adding the descriptor "injection" or "UIC" before the word "permit".	Page 3, line 28
Sarah Roberts	EPA Rg 8	Change "as a" to "into" and "well" to "wells"	Page 3, Line 4
Sarah Roberts	EPA Rg 8	insert "known" before "associated"	Page 3, Line 6

Norman Warpinski	Pinnacle-Halliburton	you indicate that shale development has expanded the geographic areas into areas previously considered unproductive. I do not think that this is true. If you look at a historical map of where drilling and fracturing have occurred, you will find that not much has changed. For example, PA, OH, WV and NY have a long history of drilling and hydraulic fracturing, along with some disposal wells. Different formations are being exploited and the scale may be different, but the regions have not changed much.	Page 3, line 9
Dave Basinger	EPA Rg 9	Reads rough, suggest: "Although not a major part of this effort, seismicity associated with hydraulic fracturing (HF) was addressed in several of the literature sources, with whichand the WG agreed with the conclusions that HF has a low likelihood of inducing significant seismicity."	Page 3, lines 22-24
Chuck Lowe	OH EPA	**Who is the intended audience?** The Ohio EPA recommends that the document be written for technical permit reviewers and inspectors as originally intended. As currently written the document appears to be intended for the general public and not for UIC program technical permit reviewers or inspectors. Page 3 states that the report is "intended to describe for UIC program management the current understandings related to induced seismicity" whereas page B-1 states that the purpose is "to develop a practical tool for the evaluation of induced seismicity". As written, the current draft report is a primer on induced seismicity and does not provide the necessary guidance to assist a permit writer or inspector evaluate the potential for induced seismicity.	Page 3, Page B-1
Norman Warpinski	Pinnacle-Halliburton	I am astounded that you missed the first most basic question. We know that all injection induces some degree of seismicity, most of it so small it is called microseismicity. The first question should be "What degree of seismicity is likely to have a negative impact on USDW's." If you do not answer this question, there is no rational methodology for proceeding with the rest. Is a magnitude -1 seismic event a problem? How about a 0? Maybe a +1? You need to have some rational for continuing.	Page 4 and 5
Bill Bates, Ross Micham, Tim Elkins	EPA Reg 5	Add the word "the" before "UIC Director".	Page 4, line 3
Bill Bates, Ross	EPA Reg 5	Suggest removing the words "unlike disposal wells" at the end of the sentence.	Page 4, line 9
Brian Stump and Chris Hayward	SMU	It would be good to add references supporting the contention that enhanced recovery projects generally pose less potential to induced seismicity. Although the physical argument in terms of fluid balance is a good one I am not sure that the data of such induced earthquakes related to enhanced recovery supports the broad nature of this statement. For example, Cogdell field in West Texas. One might also consider the Geysers where additional water is injected to balance the fluid loss-yet still this is a major area of induced earthquakes.	Page 4, lines 2-4
Dave Basinger	EPA Rg 9	Reads rough, suggest: "Injection related to enhanced recovery projects generally poses less potential to induce seismicity than a brine disposal well because pressure changes resulting from injection and production volumes partially negate off-set each other during enhanced recovery, unlike disposal wells."	Page 4, lines 7-9
Brian Stump and Chris Hayward	SMU	Stressed Faults. Since the current understanding is that the earth is critically stressed everywhere, is the implication that the stressed faults are all those faults that are favorably oriented?	Page 4-7

David Dillon	NAS	Report does not contain a "control group" and does not analyze inj characteristics of well tha have not induced seismic events. For example, Common Characteristics and Lessons Learned from Case Studies section on page 18 noted fractional flow behavior was confirmed in N. TX using falloff test and operation analysis of disposal rates and pressure exhibted enhanced responses in some wells. Report provides analysis supporting these observations an analysis of wells that have not produced seismic events might show the same characteristics. Maps provided in the report showed many other wells in the DFW, Cleburne, and AR areas. Analysis of these wells should also be analyzed to fully understand why some injection wells trigger earthquakes and others do not.	Page 5, line 21
Dave Basinger	EPA Rg 9	Ohio is notably not included in the list. It's certainly included later, but hadn't been identified at the time that list was generated? If so, perhaps footnoted as such so it doesn't appear to be an oversight.	Page 6, item 8
Norman Warpinski	Pinnacle-Halliburton	In many places you have stated that there are three components necessary for significant injection induced seismicity. I was very surprised that you did not have a fourth one – proximity to basement rocks. You discuss the importance of brittle rocks and talk about basement rocks in some places (e.g., on page 8 you note that most of the cases are related to basement rocks), but never make the final connection that since just about all of the potential cases (including cases like Rocky Mountain Arsenal and Paradox Valley) are associated with faults into basement rocks, this is should be considered a major component. Yes, there may be a few cases where disposal wells have problems in other rocks, but layered sedimentary rocks with abundant shales are much less likely to have issues. In your four case studies, the weakest potential seismicity one is the West Virginia example where injection is into the Marcellus. All of the strong cases are associated with the basement rocks.	Page 6, line 23
Brian Stump and Chris Hayward	SMU	One point that is not well developed is the orientation of the current *in situ* stress field with faults. It is worth noting that in cases where the current *in situ* stress field is optimally oriented with old or inactive faults that there might be the opportunity for inducing earthquakes along these features. I believe that this is mentioned in the USGS appendix but does not seem to have found a place in the body of the report. This association emphasizes the need to characterize both the active and inactive faults in the region as well as their geometry relative to the current *in situ* stress field.	Page 6, line 23 and Page 9, line 7
Chuck Lowe	OH EPA	Why was Ohio not included/mentioned? The assistance and/or contribution of state agencies are acknowledged in the selected case histories. ODNR should be included.	Page 6, Lines 7-15
Sarah Roberts	EPA Rg 8	note, porosity refers to quantity, not quality	Page 7, Line 3

Sarah Roberts	EPA Rg 8	Change "connections among" to "ability for fluid to move between"	Page 7, Line 4
Sarah Roberts	EPA Rg 8	maybe a more relevant example is fracture formation	Page 7, Line 7
Norman Warpinski	Pinnacle-Halliburton	why do you ignore basement rocks in the discussion of brittle behavior. I would note that basement rocks are generally the most brittle, and wells in proximity to the basement are most likely to have issues.	Page 7, lines 11-14
Ernie Majer	LBNL	What about carbonate reservoirs? If a disposal well is in a carbonate reservoir, will it automatically be rejected?	Page 7, lines 1-2
Brian Stump and Chris Hayward	SMU	The lack of ------small------ events in the historical seismic record may be due to a lack of seismometers, sparse population, and a low natural recurrence rate coupled with a short recording history. Large events (M7) would be recorded in the historical record and possibly in the paleoseismic record.	Page 8
	USGS	“history of tectonic stress” – As indicated above, the crust is stressed everywhere and there are likely faults everywhere that are highly stressed. The issue is not the “history of tectonic stress” but rather the current state of stress.	Page 8, line 20 old and Page 8, lines 17-21
Dave Basinger	EPA Rg 9	Could the report strengthen the suggestion/requirement to avoid injecting into or directly above bedrock (basement rock)? The report generally supports this, but could/should this be more strongly expressed? Our regional perspective is that this is a very high priority.	Page 8, lines 1-11
Dave Basinger	EPA Rg 9	to clarify that a lack of seismic history does not necessarily mean it is a seismically inactive area in the geologic sense, suggest "The history of seismic events in the region and the immediate area will indicate if the area continues is known to be active."	Page 8, lines 17-18
Brian Stump and Chris Hayward	SMU	In discussing the geoscience factors related to injection---induced seismicity regional factors are reviewed in this section.	Page 8, second paragraph
Ernie Majer	LBNL	Yes, Mohr-Coulomb is a main theory, but rate and state should also be mentioned (Jim Rice’s work at Harvard) it may explain some things that M-C theory does not.	Page 9
Ernie Majer	LBNL	A Table of Magnitude versus fault area would be useful (Kanamori and Anderson, 1975 BSSA 65 no 5 1073-1095), have the equations)	Page 9
Ernie Majer	LBNL	Must remember that stress drop is also important!	Page 9
Brian Stump and Chris Hayward	SMU	Wells and Coopersmith's data set was limited below M5. The implication in the paragraph is that there is a well understood or observed relationship between 7.1 and ---4. It may be that the relationships observed for moderate to large earthquake do not scale down to magnitude 2.	Page 9
Norman Warpinski	Pinnacle-Halliburton	the comment about hydraulic fracturing creating microseisms corresponding “to less than one millimeter of slip on a section of rock around a half meter long (Das and Zoback 2011)” is not correct. I do not know where Das and Zoback would have come up with this idea, but a slip radius of 0.5 meter in a typical shale with 2,000 m/s shear velocity would have a frequency of greater than 1,000 Hz (e.g., following Brune or other similar approaches), which is well above the capabilities of our instrumentation for microseismic monitoring. Since the radius is roughly proportional to the shear velocity divided by (pi x frequency) and the frequency usually ranges from 100 to 500 Hz, the typical size is from about 1 to 5 meters. This also reduces the slip distance accordingly.	Page 9,

Roy Van Ardsdale	Memphis Univ	“reduces the frictional resistance along the fault”. Actually pore pressure reduces the normal stress across a fault thereby promoting fault movement.	Page 9, line 12
	USGS	The discussion of Mohr-Coulomb failure contains some errors. A shortened, corrected version is: The Mohr-Coulomb failure criterion is the fundamental rock mechanics model describing the fracturing or motion along a fault. This criterion is described in detail by Nicholson and Wesson (1990) and Stein and Wysession (2003). The Mohr-Coulomb criterion uses the tectonic stresses on a fault, the frictional resistance of the fault materials, and the fluid pressure within the fault to determine whether or not that fault will slip. In the case of injection-induced seismicity, fluid pressures are raised within the fault, which in turn reduces the frictional resistance along the fault. Lowering the frictional resistance, means that stresses that were once not high enough to cause failure may now be high enough to cause failure. Fluid injection may relay increased fluid pressures to a fault zone at distance from the injection point. This can occur when the disposal zone is in hydraulic communication with the fault zone. Lateral and vertical reservoir pathways to a stressed fault could include natural rock fractures, injection-induced fractures, other faults or possibly other mechanisms specific to the disposal zone.	Page 9, lines 12-27 old Page 9, lines 8-19 new
Brian Stump and Chris Hayward	SMU	In view of the Cleburne and DFW experience where magnitude. 2.0 and below events generated felt reports (as well as news activity) one may want to consider adding a depth dependence to this felt scale. Shallow events and events in the US Northeast have different thresholds.	Page 10
	USGS	It is worth noting in this report that seismicity can continue well beyond the termination of fluid injection. At the Rocky Mountain Arsenal, seismicity continued long after the injection stopped. The largest three earthquakes, with magnitudes between 4.5 and 4.8, occurred over one year after injection stopped.	Page 10 old, Page 10 lines 4-6 new
	USGS	It should be clarified that fluid pressures in the formation can be raised even when injection is done under gravity feed. If the water level in the well bore rises, then the pore pressure at the injection interval will rise approximately 0.1 MPa for every 10 m rise in water level.	Page 10, line 17 old Page 10, lines 7-17 new
Sarah Roberts	EPA Rg 8	says "injection and withdrawl from injection wells" should this say "injection into Class II wells and withdrawl from production wells"?	Page 10, Line 20

Norman Warpinski	Pinnacle-Halliburton	you really should not specify a magnitude threshold for human detection. It depends very strongly on depth, earth conditions, and other parameters.	Page 10, line 24
Norman Warpinski	Pinnacle-Halliburton	it would seem to me that this would be a good place to note that the Rangely tests show that it is possible to mitigate induced seismicity.	Page 10, line 31
	USGS	The consensus within the seismological community and within the peer-reviewed seismology literature is that the earthquake sequences in Ohio are induced [*Nicholson and Wesson* , 1990; *Seeber and Armbruster* , 1993, 2004]	Page 10, line 8 old and Page 10, lines 1-4 did
Brian Stump and Chris Hayward	SMU	A citation or quantification would help demonstrate that the total energy difference for injections accompanying a small geothermal project is much less than the total energy from a large fluid disposal program.	Page 11
Brian Stump and Chris Hayward	SMU	HF events. It may be worth mentioning the Blackpool and Horn River Basin HF events	Page 11
Cliff Frohlich	UT BEG	Mention two examples of true hydrofrac-induced earthquakes. Two other examples are the 1991 California event (Kanamori and Hauksson, BSSA 1992) and the Horn River, British Columbia events (BC Oil and Gas Commission).	Page 11
Norman Warpinski	Pinnacle-Halliburton	I do not know why you would suggest that thermal stresses may be of limited applicability to brine disposal wells. We are injecting large volumes of fluid at near-surface temperatures into much hotter rocks; why wouldn't there be significant thermal stresses. You might review a 1984 paper by Perkins and Gonzalez (in SPEJ) for some understanding of its importance.	Page 11, lines 13-14
Chuck Lowe	OH EPA	The sentence order is misleading. Suggest switching the order of sentences 2 and 3 for a better flow and continuity of thought.	Page 11, Lines 26-30
Brian Stump and Chris Hayward	SMU	What is the currently acceptable proof? Based on this and other reports, it seems that the Rocky Mountain Arsenal is regarded as a study where there was proof, and the implication may be that in order to prove that a particular well is actively inducing seismicity it is necessary to show a relation between the modulation of injection activity and the modulation in earthquake activity, a particularly difficult study to find public acceptance in areas of significant population.	Page 12
Ernie Majer	LBNL	From here on I had trouble following the logic. It seemed too diffuse and did not follow your three main needs, 1) Geologic characterization; 2) Stress/pressure change; 3) Flow pathways.	Page 12, after line 24
Bill Bates, Ross Micham, Tim Elkins	EPA Reg 5	Remove the letter "s" from the word "cases".	Page 12, line 27
Ernie Majer	LBNL	I would add association between injection time and earthquake activity i.e. can you turn on and off seismicity by varying the injection (within a few weeks, maybe longer for larger injections)	Page 12, line 4
	USGS	In the course of investigating the Trinidad earthquakes, we have examined the criteria proposed by Davis and Frohlich, [1993] in view of many case histories of induced earthquakes that have been published since their report. From our perspective in 2012, we have proposed revisions to the seven questions, listed on p. 12, that render them	Page 12, lines 11-23 old Page 12, lines 13-20 new

Ernie Majer	LBNL	Wow! True more action may be necessary, but If you can turn on and off the seismicity near the injection well, then it is pretty clear, it is induced!	Page 12, lines 21-24
Brian Stump and Chris Hayward	SMU	How is the radius of 5---12 miles selected? Is it based partly on the assumed accuracy associated with the hypocenters as well as the maximum expected radius for fluid migration?	Page 13
Bill Bates, Ross Micham, Tim Elkins	EPA Reg 5	It may be useful to go into a little more detail about determining the radius of investigation. Maybe talk a little more on the spacing density of seismometers.	Page 13, line 5
Norman Warpinski	Pinnacle-Halliburton	you discuss the radius of investigation around the wellbores. This is the place where you should also discuss depth of investigation. I understand that depth is poorly constrained by the majority of the networks monitoring such local	Page 13. lines 2-7
Brian Stump and Chris Hayward	SMU	Based on our current data (M 3 events continuing) as well as the Eisner report (now published), can we still say that the frequency and magnitude of the events are statistically significantly reduced?	Page 14
Cliff Frohlich	UT BEG	Concerning seismicity in north Texas, the report states "Since the deactivation of the two wells, the frequency and magnitude of seismic events has substantially decreased." In both Cleburne and DFW the largest magnitude events have occurred since shut in of the wells.	Page 14
Scott Ausbrooks	AGS	…..after injection was initiated *at the Trammel well* , earthquake activity	Page 15, line 11
Scott Ausbrooks	AGS	See H-1 Rules attachment on Moratorium Zone: Unless otherwise approved by the Commission after notice and a hearing, no permit to drill, deepen, re-enter, recomplete or operate a Class II Disposal or Class II Commercial Disposal Well may be granted for any Class II or Class II Commercial Disposal wells in any formation within the following area ("Moratorium Zone") located in Cleburne, Conway, Faulkner, Van Buren, and White Counties. Also provided a description of moratorium area by County, Township and Range. Some restrictions pertain to all counties (?).	Page 15, line 34
Sarah Roberts	EPA Rg 8	talks about historic seismicity; how extensively and for how long had it been monitored?	Page 17, Line 5
Tom Tomastik	ODNR	Need to eliminate any statements like "this area has not been seismically active" or "historically, there had been no prior seismicity in the area" – these statements are scientifically incorrect as human activity in the United States has reports these events for only about 300 years. Geologically, we have no way of knowing what seismic activity has occurred in a given area. Since most faults have to be at critical failure to be induced, then obviously, the fault system would have failed previously due to natural stresses.	Page 17, line 5
Bill Bates, Ross Micham, Tim Elkins	EPA Reg 5	It is Region 5's understanding that ODNR received additional information from nearby REXX Energy wells shortly (~2 months) after the December earthquakes in Youngstown, OH. This data showed a fault in the general area of the well in question, rather than 20 miles away as suggested by the Pennsylvania Geological Survey. Perhaps the additional sources of data should be included.	Page 17, lines 19-22
Brian Stump and Chris Hayward	SMU	The second lesson learned is that an improved understanding of reservoir behavior in the disposal zone will lead to better characterization of induced seismicity. In general I agree with this statement but did not find quantitative evidence to support this conclusion in the case studies except in the study showing relatively long distance communication between adjacent wells.	Page 18

Brian Stump and Chris Hayward	SMU	The forth lesson learned discusses the importance of increased seismic monitoring to improve earthquake locations. I think this argument can be quantified based on the USGS appendix and that some characteristics numbers including illustrating the large errors typical in regional locations provided by USGS. I think there is an underlying issue that is not discussed here or in the Appendix. Even with close---in stations there will be tradeoffs in the estimate of event depth and the assumed P and S wave velocity model used for the location. As a result, depth will be one of the hardest parameters to estimate even with local instrumentation. There should be some recognition of this fact in the report.	Page 18
	USGS	For the case studies, it would be instructive to discuss the remedial actions taken in each of the study regions, and the results of these remedial actions. This would be useful motivation and information as to how a response paradigm to induced earthquakes could be developed.	Page 18 old and new
Norman Warpinski	Pinnacle-Halliburton	you imply that fractured flow behavior is some kind of an indicator of problems. I would hazard a guess that a majority of injection wells exhibit fractured flow behavior which improves their injectivity, but these are not all problem wells. Interpreting falloff tests after long term injection is not necessarily a simple process. What is it that you expect to get out of falloff tests that will provide any insight into the behavior?	Page 18, lines 15-16
Norman Warpinski	Pinnacle-Halliburton	you make mention of engaging seismographic expertise. I agree, but don't you think that an objective of doing this would be to hone in on the depth of the earthquakes relative to the injection zone. One would expect that this would be a very important piece of information if it could be accurately determined.	Page 18, lines 28-34
Norman Warpinski	Pinnacle-Halliburton	"lower permeability formations accepting fluids at higher pressure within the disposal zone" is kind of confusing. Even low permeability zones will have some injectivity at low pressures. As pressures increase, their injectivity will increase, but injectivity of higher permeability zones will increase more unless scaling or fines damage is increasing the skin. Are you suggesting natural fractures may start to open? Fissure opening could happen in any zone.	Page 19, line 1
Sarah Roberts	EPA Rg 8	while this is a very interesting and important point, I don't know if it fits in this bulleted list	Page 19, Line 25
Norman Warpinski	Pinnacle-Halliburton	there is discussion about operating wells below fracturing pressure. However, the fracturing pressure is liable to change with time due to increased pore pressure (increased stress) and decreased temperature (decreased stress). Is there any time sequence for measuring the stress? Should it be done at the beginning of injection and then at some prescribed intervals? Certainly you need a baseline if you want it done after some seismicity is detected.	Page 19, lines 15-17

Brian Stump and Chris Hayward	SMU	I would add the orientation of the *in situ* stress field relative to the existing faults to this list. Possibly the use if stressed fault is meant to convey this point but explicitly including the relationship between the stress field and fault orientation would strengthen the description.	Page 19, lines 31-32
Bill Smith	NAS	Recommended summarizing the usefulness of reservoir engineering plots determined from the case studies.	Page 20
Tom Tomastik	ODNR	We are assuming “homogeneous rock properties” in this report and that really does not exist in the real world. Most geologic formations are going to be heterogeneous.	Page 20, line 24
C.S. Kabir	Hess Corp	Disposal is very limited in any saline aquifer. Therefore connecting disposal of fluids to suspected fault breach, a result of seisic events is not surprising because of the limited available aquifer volume. Economides (2010) suggested inj of supercritical CO2 is equiv to inj liquid in a closed aquifer and concluded vol of inj fluid cannot normally exceed 1% of pore space. Low disposal volumes is a result of compressibility-driven phenomenon in a liq reservoir.	Page 20, line 4 and Page 24, line 14
Sarah Roberts	EPA Rg 8	change "would" to "can"	Page 20, Line 6
Brian Stump and Chris Hayward	SMU	Annular pressure tests and production logging.. Is there an example where this was done after seismic activity?	Page 22
C.S. Kabir	Hess Corp	Excessive data scatter appears to be independent of data density and is bothersome. His experiences (Izgec-Kabir 2009, 2011; Aschehoug-Kabir 2012) suggest that even the numerical derivative does not produce as much scatter as observed in some of the plots and he is open to interpreting a few wells to explore the underlying issue.	Page 22, line 12
Roy Van Ardsdale	Memphis Univ	“higher pressures would be directionally focused”. I think you should elaborate on this topic here and explain how the increased pore pressure opens fractures, or causes fracturing, perpendicular to the minimum principal stress direction.	Page 22, line 2
Bill Bates, Ross Micham, Tim Elkins	EPA Reg 5	Defining the Hall integral plot earlier in the section might help eliminate initial questions. The first time Hall integral is mentioned is page 22 line 11.	Page 22, lines 17-19
Sarah Roberts	EPA Rg 8	change "geoscience" to "geologic"? I feel like there is probably a reason geoscience was selected rather than geologic but I cannot think of another geoscience discipline that would be relevant...	Page 23, Line 29
Norman Warpinski	Pinnacle-Halliburton	I think that your decision model and site assessment should include proximity to basement as a key component, as noted at the beginning.	Page 23-25
Brian Stump and Chris Hayward	SMU	Existing disposal well. While it is brought out later in the study, it wasn't obvious to us at this point that this was being considered from a regional perspective. For example the older Cleburne injector was permitted well before the additional activity in the region.	Page 24
Roy Van Ardsdale	Memphis Univ	“especially if the well was located in a tectonically stressed region”. I think this would be better stated; as especially	Page 24, line 19
Norman Warpinski	Pinnacle-Halliburton	in the decision model, since this is an EPA study on the effect of induced seismicity on USDW’s, why isn’t there a part of the tree that asks the question “could this affect USDW’s and what would the effect be”. If the answer is no, then it is not clear why EPA is involved. You seem to be assuming that any induced seismicity is a threat to USDW’s, but there is absolutely no science that would support this assumption at this time.	Page 25

Brian Stump and Chris Hayward	SMU	In the proposed decision model, one of the considerations is “Have there been regional seismic event.” It is critical to define what is meant by regional relative to the proposed well, especially in light of relatively large uncertainties in earthquake locations using regional stations.	Page 25
Roy Van Ardsdale	Memphis Univ	Initial should not be capitalized.	Page 26, line 27
Sarah Roberts	EPA Rg 8	after reading about the three categories: operation, monitoring, and management approaches, I was looking for each of these to have their own section next. I continued to read and saw they were all explained throughout the next few sections but it may be nice to have them each summarized directly below this section to tie it together?	Page 26, Line 3
Norman Warpinski	Pinnacle-Halliburton	the “Director” determines which, if any, approaches are important depending on site specific considerations.” Shouldn’t that sentence end with the phrase “and a plausible threat to USDW’s”	Page 26, line 7
Brian Stump and Chris Hayward	SMU	I strongly endorse this statement. It is critical that multi---disciplinary approaches be implemented in order to better understand induced earthquakes. This approach includes the free exchange and sharing of databases, models and interpretations. Such an approach will provide the basis for identifying outstanding issues that might be illuminated with additional work or data. Within a research framework this cooperation provides a path forward for a better physical understanding of the processes and the development of a set of coherent best practices.	Page 27
	USGS	We generally endorse the concept of gathering more field data on injection well operations. More frequent reporting of injection volumes and critically injection pressure are needed to identify any correlations between injection well operation and seismicity. Given the complexity of the earth, it is unlikely that a one-to-one correlation between well behavior and seismicity will be found. We have already documented in the Raton Basin, for example, that some wells induce earthquakes while others injecting into the same formations do not. Experience there and elsewhere also demonstrates that some wells induce seismicity almost immediately after the start of injection, while others may see a delay of months or even years before the onset seismicity is observed.	Page 27, lines 30-34 old, Page 27, lines 30-34 new
Steve Platt	EPA Reg 3	I don't believe the data necessarily supports the statement that seismic events in WV started at lower magnitude and generally increased over time. The last recorded event, in 2012, was less than the maximum recorded event in 2010.	Page 28, lines 20-22
Norman Warpinski	Pinnacle-Halliburton	So what if the seismicity occurred in zones with naturally fractured reservoir characteristics. Maybe most disposal wells have naturally fractured reservoir characteristics. Did you study any disposal well case studies that did not have induced seismicity to see if there was any kind of a correlation? This statement is quite a reach without more information.	Page 28, lines 29-30

David Dillon	NAS	Summary of analysis does not lead directly to the common factors listed in the findings and observations. Many of these common factors could occur in wells that have not induced seismicity. Specifics listed in Table 1. Table shows there is no good correlation between test results and disposal well's causation of induced seismicity.	Page 29, line 28
Norman Warpinski	Pinnacle-Halliburton	Same issue as the previous comment. Did you study any case studies of disposal wells without induced seismicity to see what those Hall plots looked like? It may be that most or all disposal wells exhibit increased injectivity over time. There are many complex mechanisms at work in such an environment.	Page 29, lines 31-32
Brian Stump and Chris Hayward	SMU	In the case of geothermal seismic activity there is a strong public component associated with the assessment of the impact. Although this is mentioned in passing later in this report, there is no discussion of the same level of public involvement in the USDW case. Should there be some mechanism to increase public involvement and education?	Page 30
Roy Van Ardsdale	Memphis Univ	“to identify active subsurface stresses”. I suggest; to identify local principal stress directions.	Page 30, line 34
Norman Warpinski	Pinnacle-Halliburton	there is a comment that “Under-pressured reservoirs may have a larger differential of pressure buildup prior to inducing seismicity”. What is the basis for this statement? Either way the disposal is shifting Mohr’s circle to the left by the amount of pressure buildup, but if the pore pressure starts out lower, then the reservoir stress will generally be lower and there will be greater initial shear stress present. Same comment for page 31 (line 21,22).	Page 30, lines 2-3 and Page 31, lines 21-22
Brian Stump and Chris Hayward	SMU	.. with early monitoring it may be possible to reduce... One may want to consider the statements in the NAS report “ No capability to predict how reducing volumes, rates, and pressures will affect seismicity once started” and “evaluating .. is difficult because there is no cost effective way to locate unmapped faults and measure *in situ* stress.” If this report differs from the NAS, it would be useful to point out the reasoning, or if there is no disagreement perhaps to remark that this report accepts or agrees with the NAS...	Page 32
Tom Tomastik	ODNR	Anyone outside of the NTWG who edited this report should be listed as contributors also.	Page 33, WG Team or acknowledge
Chuck Lowe	OH EPA	Who should be credited with writing the document? Ohio EPA believes the primary credit for writing the document should not be given to the NTW subgroup but to the persons responsible for re-writing the document. The current draft is different in information, verbiage and organization from the original draft. It has been rewritten, expanded and re-organized by a person or persons without input or assistance from the NTW subgroup that wrote the original draft. It appears the NTW subgroup has gone from being the primary author to being a secondary reviewer.	Page 33, WG Team or acknowledge
Scott Ausbrooks	AGS	Add AGS: Arkansas Geological Survey	Page 34, between lines 3 and 4
Brian Stump and Chris Hayward	SMU	Position uncertainty. While a later appendix points out that 'many parts of the world' includes large parts of the US, this may be worth pointing out here as well.	Page 35

Brian Stump and Chris Hayward	SMU	Damage. Damage is relative and dependent on construction practices, regional and local geology, earthquake depth, and geologic and cultural hazards. The included table may lead one to consider that any earthquake under M5 could be ignored. From a public perspective this is not the case, since the Soultz France project was ended due to possible damage to structures from a M 2.9 earthquake.	Page 35
Roy Van Ardsdale	Memphis Univ	"stress changes". I suggest replacing stress changes with release of elastic strain energy.	Page 35, line 9
Brian Stump and Chris Hayward	SMU	Term stressed fault. Is that an accepted term with a citation in the literature or is this a first use here?	Page 36
Scott Ausbrooks	AGS	Revise reference: Ausbrooks, S.M. and Doerr, E., 2007, Enola Swarm Area of Faulkner County, Arkansas: GH-EQ-ENOLA-002, Arkansas Geological Survey, 1 sheet.	Page 37, lines 8 and 9
Roy Van Ardsdale	Memphis Univ	I did not see the following reference that I think belongs in this document: Cox, R.T., 1991, Possible triggering of earthquakes by underground waste disposal in the El Dorado, Arkansas area: Seismo. Res. Lett., 62: 113-122.	Reference and App K
Cliff Frohlich	UT BEG	I was concerned about the feasibility of some of the recommendations or assessment tools. In Appendix B, for example, there is a section posing questions about potential injection wells: 1) Is the area geoscience information sufficient to assess the likelihood of faults and seismic events? 2) Are the available data sufficient to characterize the reservoir pathways? 3) Is there adequate information to characterize potential reservoir pressure buildup? For almost all the tens of thousands of wells in Texas, the answers are clearly NO, NO, and NO. So what is this report really suggesting in terms of implementation of policy? Somewhat later the report suggests that seismic monitoring is a good idea. But is this a serious suggestion considering the number of wells we are talking about?	App B
Brian Stump and Chris Hayward	SMU	Should the estimated error in location accuracy (which will vary with time) be used to select the area around the well? Seismic station spacing in the US is as large as 200 miles. It might be more useful to have a accuracy related to that rather than the 100 miles. Also, it would be useful to include the lack of depth accuracy since this has often been used in news and industry arguments as to the cause of the earthquake.	App B
Chuck Lowe	OH EPA	Ohio EPA recommends confidentiality of information. The use of seismic data to support the site assessment is not addressed. If a company uses any source of seismic data (commercially available or acquired by the company) the company must have the right to require confidentiality. The data may not be made available or the reviewing agency(s) may be causing economic harm to either the company or a third party broker. The data should not be released unless written approval from the company or third party broker is received.	App B or Decision Model
	USGS	Seismic imaging does not always reveal all the faults in an area. In fact, near-vertical faults are highly likely to be missed.	App B, B-4, Lines 1-14 old App B, page B-4, lines 12-15 new.

	USGS	Relative to the cost of drilling or premature abandonment of a disposal well, seismic instrumentation is not costly. Appropriate monitoring can be procured at a reasonable cost from geophysical service companies, academic institutions and government agencies.	App B, B-8, Lines 23-25 old; App B, page B-8, lines 23-24 new
Roy Van Ardsdale	Memphis Univ	Pages 1 through B-10 have redundancies that make this section longer than it needs to be. Perhaps you are following a structural template, but it is frustrating to read.	App B, Page B-1 to B-10
Chuck Lowe	OH EPA	should read: "These ~~three~~ categories are: site assessment considerations, and operational, ~~and~~ monitoring, and management approaches."	App B, page B-1, line 28
Chuck Lowe	OH EPA	Awkward sentence revise to read "Based on these criteria, the Director may require additional information or monitoring for the protection of the USDWs."	App B, page B-1, line 32
Chuck Lowe	OH EPA	insert: "to address potential induced seismicity issues."	App B, page B-1, lines 31-32
Chuck Lowe	OH EPA	"…absence is a supportive indicator…" This could also reflect either a lack of seismic monitoring in the AOR or a lack of monitoring sensitivity by the existing network. The statement should reflect all possible conditions.	App B, page B-2, line 15
Chuck Lowe	OH EPA	change to read "… the size of the ~~seismic history search area around the well in question~~ AOR and the level …"	App B, page B-2, line 21
Roy Van Ardsdale	Memphis Univ	I suggest inserting strike-slip after near-vertical.	App B, page B-4, line 12
Chuck Lowe	OH EPA	potential proprietary information: "… evaluating available seismic surveys." This reflects the concerns addressed in earlier comments.	App B, page B-4, line 3
Chuck Lowe	OH EPA	insert "…insight about potential out of interval …"	App B, page B-5, line 14
Chuck Lowe	OH EPA	1. change to read "…volumetric estimates of ~~for~~ fluid ~~volumes~~ being emplaced in the reservoir(s)."	App B, page B-5, line 17
Chuck Lowe	OH EPA	change to read "Naturally fractured ~~disposal~~ formations ~~involving induced seismicity~~ would ~~likely~~ require a more complex analysis ~~pressure buildup prediction methods~~ to account for non-radial reservoir behavior."	App B, page B-6, line 19
Chuck Lowe	OH EPA	1. change to read "…at the end of a falloff test may ~~also~~ provide~~s~~ an assessment…"	App B, page B-6, line 22
Chuck Lowe	OH EPA	change to read "around the injection well. The increase in reservoir pressure offers insight into the magnitude of the pressure buildup in the AOR."	App B, page B-6, line 23
Chuck Lowe	OH EPA	delete these three (3) sentences.	App B, page B-6, lines 33-35

Dave Basinger	EPA Rg 9	To clarify, suggest (and may combine with the preceding line), "Pressure transient test data ~~A~~analysis of data typically requires some specialized software and technical expertise~~ to evaluate the results~~."	App B, page B-8, lines 4-5
Brian Stump and Chris Hayward	SMU	Appendix C is very useful and provides insight to petroleum engineering considerations that can be understood by the non---specialist. There needs to be a companion appendix that discusses seismological practices for the non---specialists that provides some understanding of earthquake location, the associated errors, estimates of earthquake size (magnitude and moment) and earthquake source characterization such as fault orientation, stress drops, and fault size.	App C
Chuck Lowe	OH EPA	change to read "… ways of assessing ~~injection induced seismicity~~ reservoir parameters by analyzing ~~currently~~ available data."	App C, page C-1, lines 18-19
Chuck Lowe	OH EPA	1. change to read "…address both pressure buildup and ~~the type of reservoir flow pathway present around the disposal well as well as~~ characterize(~~ing~~) the reservoir behavior …"	App C, page C-1, lines 30-33
C.S. Kabir	Hess Corp	Use of the Silin Plot: A word of caution noting that the method is applicable at very early times during the infinite-acting period. Evolving transients encountering any fault or its breach may pose theoretical issues.	App C, Page C-11
Chuck Lowe	OH EPA	The geophysical logs discussed are used to ascertain fluid movement and the protection of the USDW. The relationship to induced seismicity should be strengthened.	App C, page C-2, lines 25-34 and page C-3, lines 1-8
Dave Basinger	EPA Rg 9	Reads rough, could you clarify the line that starts with "One question" - perhaps by stating the actual question clearly?	App C, page C-26, lines 29-30
Chuck Lowe	OH EPA	Remove this paragraph.	App C, page C-3, lines 15-20
Chuck Lowe	OH EPA	change to read "Because ~~As~~ operating data is ~~was~~ more prevalent …"	App C, page C-5, line 11
Sarah Roberts	EPA Rg 8	I expect it may not be possible but it would be helpful if plots that show "red flag" situations could be fabricated and displayed	App C, Page C-6
Cliff Frohlich	UT BEG	An SMU graduate student, Ashley Howe, in 2012 finished an M.S. thesis on the Cleburne events; she has also submitted a paper to BSSA on them. Somewhere in Appendix D it is mentioned that the Texas Railroad Commission stated that no induced earthquakes have recently occurred in north Texas except those near DFW and Cleburne; however, my August 2012 paper in the journal Proceeding of the National Academy of Sciences reports several other examples. Also, both Delaine Reiter and Leo Eisner have published papers in 2012 on the DFW earthquakes.	App D

Brian Stump and Chris Hayward	SMU	The earthquakes on the maps are difficult to distinguish from the numerous red dots of gas wells. Perhaps a different colored symbol could be used. In addition to the epicenters shown on the map, one may want to add the formal error ellipse to indicate the uncertainty associated with the events.	App D and following
C.S. Kabir	Hess Corp	Interpreting falloff tests: Exercise utmost causion while interpreting the late-time response in the derivative plots because the eqivalent time causes scale compression at late times though obviously one should use the superposition time function and is an issue with all the derivative plots. He is open to interpreting a test or two to put the superposition issue to rest. Many falloff tests indicated both the positive and negative half slopes during the shut-in period. These responses are akin to mini-frac responses (Soliman et al, 2010; Soliman and Kabir 2012). Those responses clearly suggest fracture leak-off (positive half slope), followed by fracture closure (at the peak where the tow slopes intersect), and the fracture-closure period itself (negative half slope) as seen in Figs D-62 through D-64.	App D, Fig D-62 to 64
Brian Stump and Chris Hayward	SMU	The work by Eisner on the DFW Airport events has now been published. A second independent group has reanalyzed the data and published a paper as well. References Janska, Eva and Leo Eisner (2012). Ongoing seismicity in the Dallas---Fort Worth area, The Leading Edge 31, 12(2012);pp. 1462---1468. b. Reiter, Delaine, Mark Leidig, Seung---Hoon Yoo and Kevin Mayeda (2012). Source characteristics of seismicity associated with underground wastewater disposal: A case study from the Dallas---Fort Worth earthquake sequence, The Leading Edge 31, 12(2012);pp. 1454---1460.	App D, page D-4, lines 7-9
Brian Stump and Chris Hayward	SMU	Analysis of the data from the Cleburne earthquake sequence is now complete. The referenced paper was submitted to the Bulletin of the Seismological Society of America in the fall of 2012. The review is anticipated in the first quarter of 2013.	App D, page D-6, lines 30-31
Dave Basinger	EPA Rg 9	Contain two different "maximum permit pressures" for the same well; is one surface and one bhp? please revise or clarify.	App D, page D-7, lines 6-7
Scott Ausbrooks	AGS	Provided Form 3 for SRE well - not sure why so need to check completion and well information used in report.	App E
Cliff Frohlich	UT BEG	Appendix E doesn't mention Horton's 2012 paper in *Seismological Research Letters* , although it is mentioned in Appendix K.	App E
Roy Van Ardsdale	Memphis Univ	Figure E-1 should have Figure E-6 located so that when people look at Figure E-6 they know where it comes from.	App E, Figure E-1
Roy Van Ardsdale	Memphis Univ	Enola swarm is not labeled in Figure E-1.	App E, Figure E-1
Roy Van Ardsdale	Memphis Univ	Put latitude and longitude on Figure E-3.	App E, Figure E-3
Roy Van Ardsdale	Memphis Univ	Relate Figure E-3 to Fig. E-5 by putting a box on E-5 or saying something in E-3 to let reader know that seismicity in E-5 is the fault in E-3.	App E, Figure E-5

Scott Ausbrooks	AGS	Replace with more detailed Geohydrologic units provided as a picture in a provided .jpg file: Strat_Hydro_Column_NCAR	App E, Figure E-7
Roy Van Ardsdale	Memphis Univ	replace 7.7 with magnitude 7	App E, page E-1, line 24
Roy Van Ardsdale	Memphis Univ	I suggest this line should read – The steep deeper normal faults extend into the basement…	App E, page E-2, line 13
Roy Van Ardsdale	Memphis Univ	"mechanisms were N22°E". I suggest; mechanisms reveal a fault oriented N22°E…	App E, page E-2, line 2
Roy Van Ardsdale	Memphis Univ	delete the word along	App E, page E-2, line 6
Roy Van Ardsdale	Memphis Univ	In this section you talk about confining units but you neither name nor define them.	App E, page E-3
Roy Van Ardsdale	Memphis Univ	My name is mispelled and should be Van Arsdale	App E, page E-3, line 1 and elsewhere in references and on figures
Roy Van Ardsdale	Memphis Univ	Data was should be Data were	App E, page E-3, line 18
Roy Van Ardsdale	Memphis Univ	do not understand this sentence; the north end - of what?	App E, page E-3, line 3
Roy Van Ardsdale	Memphis Univ	"zones separating" should read zones between	App E, page E-3, line 7
Roy Van Ardsdale	Memphis Univ	basement at the north end of the profile is also ….	App E, page E-3, line 9
Roy Van Ardsdale	Memphis Univ	The Paleozoic section contains carbonates, shales, and sandstones overlying crystalline basement rock.	App E, page E-3, lines 5-6
Roy Van Ardsdale	Memphis Univ	replace the word "it" with, the fault in Figure E-5.	App E, page E-9, line 28
Scott Ausbrooks	AGS	Add Horton SRL article to references. Reference provided.	App E, pg E-11, between lines 3 and 4
Scott Ausbrooks	AGS	Correct vanarsdale with Van Arsdale	App E, pg E-11, line 10
Scott Ausbrooks	AGS	Correct maximum magnitude values for 1982 and 2001: 1982 - Max magnitude 4.7; 2001 - Maximum magnitude 4.7	App E, pg E-2, Table E-1
Scott Ausbrooks	AGS	Correct vanarsdale with Van Arsdale	App E, pg E-3, line 1
Scott Ausbrooks	AGS	Correct upper Pennsylvanian unconformity to upper Mississipian-Pennsylvanian unconformity	App E, pg E-3, line 3
Bill Smith	NAS	In WV, two apparent enjanced injectivity breaks occurred while well operated below 0.7 psi/ft frac gradient so should allowed pressure gradient be maintained to a lower standard than the commonly used 0.7 psi/ft.	App F
Chuck Lowe	OH EPA	Correct. The key lists the Trenton as a shale play. The light green color on the map also lists the Devonian (Ohio) and Utica. The Utica is an Ordovician Shale. This should either be emphasized or removed from the map.	App F, Figure 1

Chuck Lowe	OH EPA	Correct. The map does not have either subsea depths or what horizon it is drawn on.	App F, Figure 3
Chuck Lowe	OH EPA	Correct. The Trenton is a **limestone.** Are the historic Upper Devonian Shale/Siltstone plays or the Devonian Oriskany Sandstone of the Eastern overthrust belt being referenced?	App F. page F-2, line 3
Tom Tomastik	ODNR	In the Youngstown section – ODNR's new rules can require pressure fall-off testing, seismic monitoring, or seismic surveys. Need to eliminate the statement in the Youngstown section "Historically, there has been no prior seismicity in the area." ODNR has also hired a PhD seismologist for the UIC Section to maintain the seismic network. We have already purchased nine portable seismic stations and have five of them up and running and we are monitoring them continuously in real-time in the office through the internet. ODNR is proactively approaching the issue of induced seismicity and is conducting seismic monitoring at several new Class II injection well permit locations prior to commencement of injection operations and will continue to monitor for seismicity up to six months after initiation of injection operations. If no seismicity occurs, then these portable units will be moved to the next location.	App G
Chuck Lowe	OH EPA	Correct. The key shows the Trenton Limestone as a shale play. This should be changed to Utica/Pt. Pleasant (the principal shale target in Ohio).	App G, Figure G-1
C.S. Kabir	Hess Corp	Superposing seismic events on the modified Hall Plot: These plots are quite useful in correlating the mild stair-steps on the Hall integral with seismic events - Fig G-11 is a case in point. He had observed a rather large stair-step when the fault breach occured during CO2 injection (Aschehoug-Kabir 2012). Because no seismicity was measured, we could not independently verify this point. Connecting the Hall-integral stair-step to fault breach is a hypothesis that needs verification.	App G, Figure G-11
Chuck Lowe	OH EPA	Correct. "…the North Star 1 encountered primarily biotite, quartz, amphibole, and feldspar with undetermined trace minerals for the first 80 feet …" The ODNR report says "…consists primarily (greater than 50%) of biotite"…; however, 1) biotie is a mineral; 2) the ODNR description also states "…lesser amounts of quartz, amphibole, feldspar, and undetermined trace minerals." Discussion with ODNR indicates that this was a sample cuttings description using visual percentage estimates not an actual mineralogical analysis. The description of the mineral assemblage (with biotite in smaller %'s) is that of a gneiss. The density and Pe curves from the open hole geophysical log do not support a rock composed primarily of biotite. I'm not aware of any rock composed of 50% biotite; visual estimates of dark minerals are invariably high.	App G, page 6.2, line 7
Chuck Lowe	OH EPA	change to read "~~Comparing~~ Inclusion of the new well information with the published …" The addition of a few data points to a regional map having a large (500 foot) contour interval should not produce much change; this statement is mis-leading.	App G, page G-2, lines 12-14
Cliff Frohlich	UT BEG	I was confused about what is to be in Appendix H. I guess this depends on the report philosophy; if there is to be serious cutting, these don't need to be added. If the report is intended as a compendium of original source materials, it may be appropriate.	App H

Brian Stump and Chris Hayward	SMU	The Appendix I am envisioning is more basic discussing some of the fundamental measurements and estimates that come out of seismological data. The reason for inclusion in the report is to high light the importance of bringing together data and techniques from different disciplines in order to better address questions related to induced earthquakes and the use of existing data to understand regional seismicity.	App I
Cliff Frohlich	UT BEG	Why is Appendix I in this report if this report is about induced earthquakes, which didn't occur in this well? If this is an example of how to asses well properties using reservoir engineering methods, that should be made clearer.	App I
Doug Johnson	RRC of TX	Appendix I did not involve seismicity and should not be in this report	App I
	USGS	**REFERENCES**	App K, References
	USGS	Davis, S. D., and C. Frohlich (1993), by circles that are sized relative to their magnitude. Red circles are earthquakes that occurred before the installation of the 12 station temporary network by USGS on 9/10/2001. Blue circles are earthquakes that occurred after installation of the tempora, *Seismological Research Letters* , *64* , 207-224.	App K, References
	USGS	Häring, M. O., U. Schanz, F. Ladner, and B. C. Dyer (2008), Characterisation of the Basel 1 enhanced geothermal system, *Geothermics* , *37* (5), 469-495, doi:10.1016/j.geothermics.2008.06.002.	App K, References
	USGS	Klose, C. (2007), Shallow seismicity in stable continental regions, *Seismological Research Letters* , *78* (5), 554-562.	App K, References
	USGS	National Research Council (2012), *Induced Seismicity Potential in Energy Technologies Prepublication* .	App K, References
	USGS	Nicholson, C., and R. L. Wesson (1990), Earthquake hazard associated with deep well injection: A report to the U.S. Environmental Protection Agency, *US Geological Survey Bulletin* , *1951* , 74pp.	App K, References
	USGS	Seeber, L., and J. Armbruster (1993), Natural and induced seismicity in the Lake Erie-Lake Ontario region: reactivation of ancient faults with little neotectonic displacement, *Géographie physique et Quaternaire*, *47*(3), 363-378.	App K, References
	USGS	Seeber, L., and J. Armbruster (2004), A fluid-injection-triggered earthquake sequence in Ashtabula, Ohio: Implications for seismogenesis in stable continental regions, *Bulletin of the Seismological Society of America* , *94* (1), 76-87.	App K, References
	USGS	Stein, S., and M. Wysession (2003), *An Introduction to Seismology, Earthquakes, and Earth Structure* , Blackwell Publishing, Oxford, UK.	App K, References
	USGS	Townend, J., and M. D. Zoback (2000), How faulting keeps the crust strong, *Geology* , *28* (5), 399-402, doi:10.1130/0091-7613(2000)028<0399:HFKTCS>2.3.CO;2.	App K, References

Cliff Frohlich	UT BEG	Additional references: BC Oil and Gas Commission, 2012, Investigation of Observed Seismicity in the Horn River Basin, 29 pp. Frohlich, C. (2012). Two-year survey comparing earthquake activity and injection-well locations in the Barnett Shale, Texas, Proc. Nat. Acad. Sci., 109, 13934-13938, doi:10.1073/pnas.1207728109. Howe, A., M. (2012). Analysis of Cleburne Earthquakes from June 2009 to June 2010, M.S. thesis, Southern Methodist University, 102 pp. Howe---Justinic, A.M., B.S. Stump, C. Hayward, and C. Frohlich (2012, submitted). Analysis of the Cleburne earthquake sequence from June 2009 to June 2010: Bulletin of the Seismological Society of America. Janska, E. and L. Eisner (2012). Ongoing seismicity in the Dallas-Fort Worth area, The Leading Edge, 31, 1462-1468. Kanamori, H. and E. Hauksson (1992). A slow earthquake in the Santa Maria Basin, California: Bulletin of the Seismological Society of America, 82 2087-2096. Reiter, D., M. Leidig, S.-H. Yoo and K. Mayeda (2012). Source characteristics of seismicity associated with underground wastewater disposal: A case study from the 2008 Dallas-Fort Worth earthquake sequence, The Leading Edge, 31, 1454-1460.	App K, References
Cliff Frohlich	UT BEG	Table L-2 in Appendix L states that the ISC requires an access fee. This is untrue: the ISC Bulletin is freely available online. http://www.isc.ac.uk/iscbulletin/search/bulletin/interactive/	App L
Brian Stump and Chris Hayward	SMU	The report by the USGS in Appendix M addresses specific questions that were posed to them and as such provide useful information.	App M
Brian Stump and Chris Hayward	SMU	Appendix M also makes some generic suggestions such as preinstalling a local network prior to injection, measuring in situ stress, but does not suggest enough specifics to indicate how much of a burden this might be. For example, roughly what range of recording time and detection thresholds might be needed? What is the cost relative to injection operations? How would in situ stress be measured and on what spacing?	App M
David Dillon	NAS	SUMMARY OF REPORT DATA (Table 1)	

		Well Name:	Geologic Indications at time of permitting:
		North Texas	
		DFW C1DE	NO(1)
		DFW North A1DM	NO(1)
		Cleburne Tx, Vicinity	
		Sparks SWD 1	NO(1)
		S. Mann SWD 1	NO(1)
		S. Cleburne SWD 1	NO(1)
		Johnson Salty SWD II	NO(1)
		Johnson Salty SWD III	NO(1)
		Cleburne Yard SWD 1	NO(1)
		Johnson Co. SWD 1	NO(1)
		Central Arkansas	
		Moore Estate 1-22	NO(2)
		Wayne L Edgron 1	NO(2)
		Trammel 7-13 1-8D	NO(2)
		SRE 8-12 1-17 SWD	NO(2)
		West Virginia	
		Elk Valley Land SWD 1	-
		Youngstown Ohio	
		Northstar 1	NO
		(1) Your report notes the TRRC reviewed the permitting actions for these wells and found no indications of potential induced seismicity. (Page D	
		(2) Although your report does not specifically make this statement, I have assumed the initial permit review of the Central Arkansas injection we	
		(3) Your report is silent concerning the correlation of the Hall Plot and Earthquake frequency of the DFW North A1DM. However, I see a correlat	
		(4) This conclusion is from my own analysis of the tandem plots. Your report is silent on your interpretations.	
		(5) This well was apparently hydraulically fractured prior to conversion to injection. (Page E-9, line 9.) Were the other Central Arkansas wells als	

Action		

Beyond the scope of WG report, but could retain for further consideration in other context.		

Replaced J with K		
No change		
Changed		

Added injection		
Should we footnote or add corrective action to the glossary?		
Revised sentence on page 1. "The report focused on Class II disposal operations as these wells have been suspected of inducing seismicity, including new geographic areas with oil and gas production activities resulting in a need for Class II disposal."		
Not changed. Talking about disposal so would be a buildup in pressure. Does this imply when pressure decreased after inj stopped that causes seismicity?		
Agree. No change.		
Added critically as descriptor throughout document		
Revised sentences on page 2. Removed supportive and added conclusive and recommended text from Warpinski below. Revised sentence on page 19 res techniques not conclusive		
No change for this comment		

Removed supportive. Added "assuming there is an accurate history of seismic monitoring in the region of the injection well."		
Revised sentence based on comments received.		
Added sentences to reflect collaborative efforts.		
Clarified added geologic and geophysic		
Changed		
Changed		

State what we didn't do…		

Removed statements that USGS identified as unclear in defining tectonic history.		

Replaced existing section with language suggested by USGS with one minor clarification. Replaced “this” (see deletion) with “pressure buildup transference.		
Added text both here and in the Report Findings and Observation section to address USGS comment in Additional Revisions about Rocky Mountain Arsenal.		
EPA agrees that fluid pressures in the formation can rise under gravity feed. The intent of the original statement had been to describe the timeline of actions that had been taken, not to imply that conversion to gravity feed would eliminate that potential. We have edited to more explicitly define what action was taken and specifying the implications it would have had for pressure.		

To address USGS comment, we removed text implying a conclusive interpretation and added		
The questions are reported here as drawn from the cited paper. The suggested USGS questions are unpublished and represent additional		

EPA will consider this proposed addition as part of the contributor comment process. Further input from USGS with more specific information about what they recommend should be included could be useful. Lessons learned were consolidated in this section and remedial actions taken by each state agency are also provided in each Case Study Appendix.		

Need to clarify limitations of assumption		

USGS conditionally agreed so no edits were made. EPA will consider the proposed detail recommended by USGS as part of the contributor comment process.		

Added		

Clarified text to address USGS comment: If seismic data are available, a reanalysis of seismic data may help identify any deep seated faults, and if present, the extent of the fault or associated fractures, although some faults, such as those that are near-vertical, may be missed.		

Deleted"are costly" to address USGS comment.		
Changed		
Changed		
Changed		

Changed		

Correlation using Tandem Hall Plot:	Pressure fall off Test:	Comments:
NO	-	This well was shut in because it was closest to Earthquakes.
YES(3)	-	
NO	YES	Fall off test showed fracture system.
NO	-	
NO	-	This well was shut in because it was closest to earthquakes.
YES	-	
YES	-	
YES	-	
NO	-	
		All Central Arkansas wells were shut in.
YES(4)	-	
-	YES	Fall off test un-analyzable.
NO(4)	YES	Fall off test showed fracture system.
NO(4)	YES(5)	Fall off test showed fracture system.
YES	-	Well was hydraulically fractured prior to injection. Injection volumes and pressures were limited to control induced seismic events.
-	-	Well was shut in.

-6, lines 18-20 and Page D-14, lines lines 5-8.)

ells did not indicate a potential for induced seismicity based on the fact that the Guy-Greenbrier fault ion to the first set of seismic events at a cumulative injection of 310,000 bbls.

o hydraulically fractured prior to injection? If true, this would definitely skew the results of any fall off